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Technology Trends Colloquium Volume I—Rapporteur's Report

29 March – 1 April 1978
United States Naval Academy
Annapolis, Maryland

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TECHNOLOGY TRENDS COLLOQUIUM

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JOINT DEFENSE RESEARCH AND ENGINEERING -
INTELLIGENCE COMMUNITY PUBLICATION

CONTENTS

FOREWORD

This publication describes presentations and discussions at a colloquium conducted over a four-day period by a mix of technologists, systems designers and managers, intelligence analysts, and operational military. The colloquium was part of a joint Defense Research & Engineering - Intelligence Community technology forecast to determine what technology will be most significant for military weapon systems of the United States and the USSR for the rest of this century.

Technology forecasts are normally strongest in their statement of technical possibilities; and weakest in their relevance to political-economic-structural-demographic-human reactions and in their recognition of cross-impacts or substitutions. The mix of technical disciplines, future environment topics, and operational personnel was an intentional attempt to overcome such shortcomings.

The year 2000, or twenty years hence, may sound like the far future - a realm for wild thoughts. Unfortunately, many people concerned with defense planning are awed by a rigid ten-year acquisition cycle, and a ten- to thirty-year life cycle for deployed systems. The future appears to be known, and indeed no one would suggest that much of the equipment now or soon to be deployed will not still be used in the year 2000. In the past, however, major changes in equipments have evolved within a decade (e.g., the ICBM) to dramatically change war-fighting capability and significantly the perception of military strength. Quoting Peter Drucker, the proper rule is not, "whatever we do we'll do forever," but "whatever we do today will...be a candidate for abandonment within a fairly short period of years." The possibilities described in this publication should stimulate abandonment of the "more of the same" viewpoint.

The impetus for this colloquium came from Admiral Stansfield Turner. He engaged others in his idea and gave emphasis to the mix of technical and operational people. The colloquium benefited significantly from the co-sponsorship and active participation of Dr. William J. Perry, Under Secretary of Defense for Research & Engineering; as well as the guidance and active participation of the steering group composed of Dr. John Deutch, Director of Energy Research,

DOE; Dr. Stephen Lukasik, Senior Vice President of RAND Corporation; and Dr. Frank Press, Presidential Science Adviser. Ultimately, the fact of the colloquium and its content rests on all the participants who generously gave their knowledge and talents to the undertaking.

The text which follows is arranged by logical grouping of materials from the colloquium exchange. Every effort was made to give an accurate, though brief, account of main points. Any errors or misrepresentations contained in this report are unintentional and regretted. Individual papers prepared for and given at the colloquium are contained in the separate volume, and are commended to the reader as a more thorough treatment of the individual topics.

SUMMARY

The tasks laid before the colloquium were to identify where important technologies are going and where the leverage for military significance is in these technologies--for the US and/or for the USSR. This was not a comparative assessment of the United States and USSR. Technological possibilities were treated as neutral--that is, capable of exploitation by either nation, depending upon its institutions and purposes.

Forty technologies, systems, and conflict descriptions were selected beforehand for their likely significance. These formed the core of the materials presented--and thereby the future prospects.

These results do suggest priorities. For DOD activities their importance can be in the opportunities now seen to be significant, in the possibilities which are not prematurely foreclosed, and in the stimulation to think about a future different than a simple extension of today. Their importance for the intelligence community can be in the recognition of where US designs may depend upon threat definition or target signature variations, e.g., cruise missile defenses; in the identification of future technologies which need to be watched; in the understanding of the US (blue side) development, acquisition and operational strengths and problems; and in the recognition of research and development fields where information or solutions found by other nations could prove helpful in US developments.

Future Possibilities

- Flexibility gains, and thereby the capability for effective application of forces, appeared to the participants as the most significant military outcome from a number of these technologies. The explosion of data processing applications possible through large-scale integration, processing at the sensor, and cheapness is foremost in impact. Applications to weapons and to radar are of course expected of hardware designers. Application to evolve geographically and functionally distributed systems for target location, unit position location, air defense, and so on will provide for battlefield portrayal and the survivability of command and control. Most significantly, application to maintenance tasks, to multiple purpose maintenance tools, and to equipments capable of field changes in function will effect radical removal of logistical constraints on force operations.

A second source of flexibility gain is expected to be the wide use of insensitive or "wooden" explosives and propellants. These, used in smart and barrage weapons, eliminate the handling, storage and fabrication constraints now necessitated by fear of fire or accidental detonation. VTOL is a third source. VTOL aircraft equal in range-payload capability to today's fixed-wing aircraft can be available in the 1990s. A fourth source is the design of battlefield surveillance and weapons to explicitly gain the advantages of night and bad weather operations. The millimeter wave radar for these short-range applications is a likely consequence.

The last of the items identified with flexibility is the integration of small team operations and equipments in a manner analogous to the development of a tactical aircraft. These teams for both main force and special operations can thereby realize the protection, the target kill, and the fire/force direction potential from new weapons, sensors, computation and communications.

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New Needs and New Approaches

Technologies were the focus, but beyond identifying what is technically possible is the question of how to make it possible. The disparity between the US and the USSR in fielding of new systems was very much the concern of the participants. The issue is not whether US technology can better fill a military need than can Soviet technology; but whether we can reverse our difficulties of recent years in choosing, designing, and producing systems which work, are assimilated, and are of reasonable cost. [redacted]

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Real concern was expressed about the attention given by the Soviets to continuous, including nuclear-biological-chemical, warfare in their doctrine, their equipments, and their training. [redacted]

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Continuous warfare was one of the forms of future conflict discussed in the colloquium; force differences responsive to a concept of non-mutual assured destruction, to a world of nuclear proliferation, and to small unit type actions were others discussed. Inadequate as these were in covering the spectrum of future needs, [redacted]

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Perhaps one of the more pervasive thoughts put forward in the colloquium was that of information war. Strategic intelligence is updated in bursts occurring in a matter of months or years. In a relatively stable regime of technical collection the capabilities of the collector tend to become known, and thus culpable to deception. A carefully designed

sequence of messages can cause reliance upon false input data and decision logic e.g. a designer is vulnerable to wrong or deceptive signature data. Furthermore, new vulnerabilities to tactical intelligence, and in actual engagements, result from the explosive use of information to optimize force and weapon allocation and control precision weapons.

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The colloquium's focus was upon technologies for weapon systems. Unintentionally, this appears to reflect the implicit assumption that machines and technology determine the outcome of wars. Those of this persuasion are impressed with the destructive power of modern weapons and view military personnel as rather unreliable machine-tenders whose function is to keep the equipment running. Fortunately, the operational participants present forcefully challenged this attitude much to the benefit of the colloquium's product.

KEYNOTE REMARKS

Dr. Perry gave the keynote charge to the colloquium. He first drew attention to two aspects of the organization: that it was a joint undertaking by two elements of the government, Defense and the Intelligence Community and, more significantly, that it represented a joining of forces between the scientific and national security communities. He noted that the latter communities had worked together in earlier years--with pride--and expressed his hope that this undertaking was a harkening of the better things to come.

He identified his two major themes for the colloquium: first, that of major military competition and, second, what science and technology has to do with that competition.

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He noted that the competition is not only military, but is economic and has to do with the quality of life and the ability to maintain freedom of choice. In these other areas we are winning the competition. [redacted] STAT

He cited President Brezhnev on the significance of science and technology in this competition. This he agreed with, noting that we have very fundamental advantages in this country in our industrial base and in our technological base. The issue is how to most effectively exploit this science and technology base--we must be extremely selective.

Dr. Perry said we have made choices with our R&D dollars in the past and that has led to the military capability we have today. [redacted]

The task he placed upon the colloquium was to identify where the technology is going and to identify where the leverage is in that technology and military systems.

TECHNOLOGICAL FUTURES

The colloquium was a 3-day snapshot of technology futures and possible military applications. The results are an input to a forecast, intended thereby to be a starting point for the harder task of resource allocation.

Dr. Davis in her summary provided a chronological listing of the technology presentations in terms of radical changes, incremental changes, and no anticipated changes. She noted the amazing and spontaneous consensus as to the constituents of US technological infrastructure for the next 20 or so years. [redacted], STAT

She identified some technologies which need watching because too little attention has been directed to them, [redacted] STAT

Dr. Lukasik said the approach in the systems discussions had been to focus upon a set of systems that would reasonably span the future needs and relevant technologies--space systems, battlefield systems, etc. He related systems and technologies by a listing of technologies which had come up in the systems discussions. These include some overlaps with the lists of Dr. Davis, but also some differences. [redacted] STAT

He drew attention at one topic from the systems discussion; namely, the one addressed by Dr. Rona entitled information systems (or information war). The future attainment of higher and higher levels of precision in surveillance, weapon use, and force allocation carries with it the greater vulnerability to deception prior to conflict or actual confusion and destruction during conflict by targeted actions against command-and-control links. This topic needs constant attention, not the afterthought customarily given countermeasures.

Many of these technologies offer new or enhanced military capabilities which will impact--and possibly cause major change in future forces. [redacted] The extent to which such changes are foreseen, and actually occur, in US forces depends in part upon the stimulation generated by the materials of this colloquium.

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Data Processors

The last decades saw the development and use of the programmable electronic computer, then the transistor, and now the present day silicon chip with its large-scale integrated (LSI) circuits. The cost per function has dropped dramatically so that inexpensive hand calculators and related microprocessors and minicomputers are now widely used commercially. Further integration is part of the future; but, more significantly, with low-cost processing many new tasks will be undertaken that today are uneconomical or not thought of. Large amounts of energy and force can be controlled in a manner similar to the way the brain directs the action of the muscles. This technology was thus seen by those at the colloquium as key, whether the application was toward separation of signals from clutter, guidance of missiles, distributed systems operations, or tools for maintenance and logistics operations in support of combat teams.

Dr. Dertouzos described the magnitude of expected hardware changes in memories and processors. By the late 1980s a million-bit chip memory will provide the equivalent of today's $100,000 computer for a few hundred dollars--purchasable for the homeowner or soldier. Similarly, by the late 1980s we will have available logic processors of 1 million to 5 million instructions per second (MIPS) at today's prices ($50 to $100). The significance by today's standards is that microprocessors will permeate instrumentation and control functions, individual use of computers will have a substantial qualitative impact on the individual's access to services and overall performance, and geographically distributed computer-communications systems will become the rule.

Radically new technologies may further increase memories in capacity and reduce costs. Single processor machines may be extended to 200 to 300 MIPS. However, these and even larger processing rates are more likely to be achieved by

multi-processors. He saw little advancement in input/output devices with continued reliance on the cathode ray tube, printer devices, and the keyboard. He noted that researchers are still struggling to construct programs that can comprehend spoken English. The significant exception will be that of the direct sensor computer interface.

The central processing units with large memories of today are a natural consequence of the considerably higher cost of logic switching or computation in contrast with that of memory storage. Now storing and logic costs are comparable, and we have the microprocessor. Mr. Joseph addressed microprocessors futures. He emphasized the rapidity of change. Until the late 1960s a new maxicomputer generation was developed about every six years, but since 1971 a new microprocessor generation has occurred every two years--small enough now and at sufficiently low cost to be integrated into common objects to give them intelligence. The integration will advance faster because interconnections are costly in power, maintenance, reliability, etc. Whereas the penalty for a signal now leaving the chip versus staying on the chip requires a hundred times more power, in a few years the number of circuits on a chip will increase by more than 10 times, and the power penalty will be a thousand to one--dictating designs where few signals leave the chip/wafer. Initially microprocessor hardware will be incorporated into computers and other machines, but he believes that, by 1980, entire systems will be integrated onto semiconductor wafers.

Dr. Dertouzos said these developments in processing hardware, the direct interface of sensors and actuators with processors, and the sizable improvement expected in bandwidth cost (glass fibers) bear directly on the instrumentation and control applications--and will bring about new levels of performance for individual equipment. New designs in such things as ships, airplanes, vehicles, buildings will come about by at least replacing heavy multiwire bundles with few glass fibers that link packet-oriented processing hardware.

Mr. Joseph added possibilities for dispersed operations that could be of significant security interest. A machine-like, nongeographically targetable, microminiaturized factory will produce end products. A mobile unit will have the versatility for complete maintenance of military equipments. Information transfers will substitute for the transfer of people and things, including where adaptation thereby of an appliance (tool) at a remote location performs a different function.

[redacted] He foresees the ability to imbed micro-processor-like logic at the interface of complex systems, thereby allowing such systems to be used by the uninitiated and untrained, to aid immeasurably in closing the gap. STAT

Similarly, he saw the significance of the microprocessor future for the military as offering the elimination of technological obsolescence for defense systems. These can be designed for continued/constant piecemeal updating, which will permit systems, vehicles, missiles, and so on to be readily adapted to a changed threat or a different physical environment. This means saving in major system buys, savings of energy, and savings of materials.

Technology can be the driver for individual equipments. Dr. Dertouzos noted by contrast that while the technology will make distributed systems possible, the principal force behind distributed systems is simply the natural geographical distribution of the collectors and users. The extent to which these systems become widespread depends critically upon the evolution of languages and operating systems designs. The most dominant application is likely to be clerical and logistic support automation, that is, the mail and message systems, text editing and preparation, maintenance of records, and clerical functions. Other applications include military intelligence, where inputs can be linked to an informational structure and retrieved inferentially and associatively rather than by key words; commands and assessment of forces issued over widespread formations; and stationery and mobile radars netted.

Dr. Hart joined in to carry the possibilities offered by greatly expanded memories and processor capabilities to even more difficult tasks. He contrasted conventional computer programs with the work in Artificial Intelligence (AI). Conventional programs ordinarily perform an inflexible operation upon a rigid set of inputs. Clearly, this speed and processing power ought to be more responsive to variability in inputs and unanticipated queries. AI achieves this in part by incorporation within the system of a substantial body of knowledge about the problem. For example, a system for analyzing aerial photographs can contain more than the visual appearance of trucks; it can contain relations

between trucks and roads, rivers, and bridges and relations between buildings and roads and so forth. The AI program can thereby interpret and analyze inputs such as photographic imagery, generate and execute a routine to answer the query, and measure the output against a desired goal.

Within the past few years, AI systems have demonstrated experimentally that they can provide consultation services to physicians on problems of medical diagnosis; determine the structure of large organic molecules from their mass spectra; analyze aerial imagery to monitor ship movements; deduce, from the content of data bases, the answers to questions posed in ordinary ungrammatical English; interpret continuous human speech about restricted domains of discourse; and control robotic vehicles and manipulators on the basis of video and other sensory input. He cited possible future military applications: the direction of multisensors on EW surveillance platform by verification of anticipated emitter presence or recognition of gaps in the current electronic order of battle; the monitoring of a stream of logistics data to determine critical exceptions to the execution of a plan; the interrogation, in ordinary English, of a set of distributed computerized data bases to form an assessment of assets or to test the feasibility of a contingency plan.

Dr. Hart saw the growth of AI to depend upon the acquisition, representation and use of knowledge. The discussion suggested an example. The enormous gain in oceans knowledge projected by Dr. Wunsch, as exploited incrementally by AI programs could accelerate knowledge of the oceans and also be applied to ocean surveillance, surface vehicle weather avoidance, and sensor designs. He saw the exploitation of multiprocessors as a further source of AI growth. Designs involving hundreds of general purpose processors or millions of simple logic units can provide the large amounts of computation AI systems typically require. Dr. Dertouzos noted that multiprocessor systems will be needed to achieve processing rates of 1,000 MIPS and up for tasks like weather forecasting, partial differential equation operations, and speech processing. Unfortunately little development of multiprocessor organization is under way.

Discussion brought out an issue concerning the growth of microprocessor systems, distributed systems and multiprocessor systems: namely, the absence of software, the difficulties and high cost of programming, and the availability of programmers. Dr. Dertouzos suggested the solutions

probably will utilize natural-language filters that precede other programs, and larger amounts of structured knowledge with relatively few processing rules. Mr. Joseph carried this point about programming cost a step further suggesting the future approach would be counterintuitive. Today the design of future systems must be software compatible with old systems, since it costs about $50 to develop a single line of new code. But we overlook the life cycle cost to maintain that line, which involves thousands of dollars because the past programs are in low-level languages. In the future we should throw away the old program and redo in a higher level language--replaceable dedicated computers on a chip will further this direction by casting software into hardware.

This means it will be cheaper to buy a new chip in order to replace the program. There were questions whether the military could constitute a significant enough market to make this approach economical. Mr. Joseph stated his belief that the costs will indeed be cheap enough to meet the special purpose needs of the military.

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Computers and data processing naturally brought the discussion to command and control as a topic. The new technology facilitates local processing. Dr. Rona emphasized how the analogous biological functions work well independently--decoupled. Decentralization offers the benefit of local tasks well done and reduces the vulnerability to countermeasures by the enemy. Dr. Davis also emphasized in her summary remarks the group's view of strong need for decentralizations.

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The ever present concern over the adequacy of NATO air defenses was the subject of much discussion, but no concensus; except to affirm that short-range systems will be key.

The importance of continuous warfare and nuclear, biological and chemical (NBC) warfare was recognized as pervasive if real preparations were undertaken. Some technologies for night vision, for forward repair, and for protection were cited but no participant suggested that the magnitude of change was even understood.

The infyonics concept for integral development of small units, their equipment, and their support excited most participants as an approach likely to maximize the exploitation of new technology and thereby gain real leverage for US land forces. Other than the new technologies two ideas were central. First, that the small unit be developed in an analogous fashion as that of a tactical aircraft instead of the current practice of appending gadgets onto men in the unit. Second, that the mission for these units be "engage and defeat," not "close with and destroy the enemy by fire and maneuver" as currently written. Defeat-not-destroy better recognizes the operational concepts within which a unit can best employ the new technologies--and the support available to it--while also recognizing "close with and destroy" is an unlikely task for a small unit facing a tank or armed helicopter. General Gray cited the Marine Sting Ray concept, and the ARPA Small Independent Action Force (SIAF) as past examples of such emphases--but without the advantages of the sensor, weapons, and processing technologies soon to be available. Several emphasized that however appropriate the development of small units was for low-level conflict, it was equally essential to large-force operations of the future.

General Dickinson along with General Gray and others cited what they saw as the tremendous potential from the new technologies for logistics. Force projection and sustained operations are dragged down or made possible by logistic support [redacted] New technologies [redacted] are: weapons which will hit what they are aimed at, the miniaturization of equipment, the processing available to anticipate and speed up response, field reprogrammable tools and equipments, and the insensitive explosives. Dr. Bement's projection of STAT

battlefield "cloning" of repair parts for existing or captured equipments added to the excitement for vast improvement in logistics and maintenance. The radical change in maintenance and logistics was seen as most significant because of the freedom thereby created for combat unit operations.

Life Sciences

Dr. Doty described the life sciences as in a state of vigorous growth and likely to remain so throughout the remainder of this century. He noted there have been 5,000 PhDs per year in the life sciences over the past half dozen years in comparison with declining numbers in the physical sciences and engineering (3400 and 2400 respectively in 1976). Thus while he could find no consensus on what discoveries will be made 15 to 20 years hence, he emphasized that the field is alive with the potential of discovery and utility.

General Augerson characterized the US man in combat. The soldier is no longer from the small town or farm who is comfortable out of doors. But rather, few will have worked with cars, fixed radios or fired a weapon as youth. For many, all impressive technology is imported (such as Japanese electronics) and domestic goods are subject to recall. Typically, equipments are undersupported, and supply austere in the extreme. If the war is in Central Europe there will be concern about dependents, if elsewhere, a national consensus may be lacking. Tactical dispersal, isolation in-fighting vehicles, and disrupted communications put serious barriers between the soldier and the supporting group with which he identifies. The equipment imposes acoustical, acceleration, thermal and toxic stresses close to tolerance limits. Intense, sustained around-the-clock combat in fluid and confusing circumstances can be expected. With no sleep people become ineffective in about three days, units and command sooner. Sustained military performance is possible with three hours of sleep per day.

Regarding lethal, toxic or disabling chemicals and drugs Dr. Doty doubted lethal agents would become any more lethal than present nerve gases. Nonlethal toxic or disabling agents are somewhat different. Nevertheless for them as well as the lethal agents he said the problems are not with the deficiency of the chemical, but with the delivery system. The uncertainty is in the domain which they will affect, and the duration of their concentration (or lethality). Similarly,

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General Augerson summed his remarks by noting the adaptability of people to chemical weapons in World War I, and indeed the ability to continue WWII operations in the presence of high casualty densities, suggests that we could be capable of prevailing if such weapons are used. Today the difficulty of detecting chemical, biological agents or radiation without special equipment is a major psychological problem affecting the way troops feel about such threats. Defensive, or offensive, developments will be a waste of money if attention is not paid to training, discipline, indoctrination and practice on the part of military personnel and commanders so that NBC operations are drilled to where they are automatic and assimilated fully into military operations.

Dr. Doty addressed the topic of genetic engineering. He saw genetic engineering in this century limited to exploiting the transfer of genes from higher organisms into bacteria and viruses in order to manufacture important products of the higher organisms, rather than the introduction of genes from one higher organism into the stem cells of another. The latter, schemes of significantly changing humans, seems a very long way off. He pointed out that the combatants for this century are born or will be within the next five years.

Dr. Doty said the apparent mismatch between the onrush of the life sciences and the modest impact in matters relating to national security was cause for question. There is no counterpart in the life sciences to the R&D community in the physical sciences constantly innovating and applying new developments or discoveries--except in limited areas such as the pharmaceutical industry. He thought the question serious enough to be examined in a deeper manner than this brief forecast permitted.

Naval Combat

Surface ships and submarines are presented in that order in this section. Not large ships, but rather smaller advanced surface vehicles were the subject. New possibilities for undersea vehicles for combat and as work vehicles were presented and discussed, as well as new ideas for submarine operations.

Mr. Mantle presented candidates for advanced naval surface vehicles for the year 2000. These were hydrofoils, air cushion vehicles (ACVs), surface effect ships (SESs), small waterplane-area twin-hulled (SWATH) ships, planing craft and wing-in-ground effect (WIG) vehicles. Normally these are sized in the 1,000-3,000-ton class, with the SES and SWATH also considered as possible aircraft carriers. Several of these offer revolutionary performance features such as calm water speeds up to 100 knots (three times today's displacement ships), seakeeping features that would virtually eliminate seasickness, and impressive maneuverability. For example, the 40- to 70-knot speed of the hydrofoil, ACVs and SESs offer the opportunity of an ASW vehicle to sprint/listen ahead of a convoy. The SWATH has the sea-keeping characteristics of much larger ships and thus could serve as a mini-carrier since two or three could be constructed for the cost of one large carrier. However, the small high speed vehicles cost the same as large medium speed displacement ships

(3,000-ton displacement, 80-knot high speed ship costs as much as a 10,000 ton 35 knot displacement ship) and thus new roles rather than competing roles need to be explored for such high speed platforms.

Speed, seakeeping, size and cost are the major considerations. Technological opportunities exist to extend capabilities or overcome some of the recognized shortcomings, for example a variablegeometry foil can add a 70-knot dash capability to a 50-knot cruise hydrofoil at no loss in seakeeping capability, supercritical hull designs can eliminate pounding at the bow for planing craft, and slim designs can give the SES an ability to operate at low speeds similar to that it possesses at high speeds.

He said introduction of these vehicles into the fleet is unlikely to be the result of a technological achievement, but rather the result of experimentation with smaller and slower versions of these vehicles. Fleet use of ACV and SES at 2,000 to 10,000 tons, but 40 to 70 knots in lieu of 100 knots, and hydrofoils at 200 to 2,500 tons and 50 to 70 knots would provide the opportunity to test the concepts and develop military applications. Other navies operate these type vehicles in numbers greater than the conventional US Navy fleet today. The Soviets have a large amphibious force of ACVs together with over 800 hydrofoils combined in Soviet Navy and civilian operations. Similar experience, rather than any specific technical development, is likely to develop a military role for these vehicles.

General Gray drew attention to the advantages these high-speed platforms could have for a mobile force to land 1,000 miles away, overnight, in weather of our choice. Support could be provided by platform use for VTOL, surveillance, and communications. Used for a precursor force or time-limited operation, these vehicles could offer unique advantages.

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and development is on highly reliable optical sources beyond one-micron wavelengths. From this, low-loss optical communication systems are likely in the 1980s with concomitant development toward optical integrated circuits. He believes the move from discretes to integrated optics will not take as long as it did from the transistor to integrated electronic circuits.

Basically he described preparation activities as having become more sophisticated. Molecular beam epitaxy (MBE) allows the preparation of almost monoatomic layers of programmed composition. Thus the possibilities for nonequilibrium structures and materials previously unobtainable are manifest. The detectors for the space and tactical surveillance described by Mr. Justice are one obviously important application.

Dr. Bement addressed the matter of <u>other materials</u>, but first noted that optical sensors and diphasic composite materials offer, as undersea acoustic sensors, the potential of order-of-magnitude improvements in acoustic response and greatly extended depths of application. Even such currently available materials as fiber optic hydrophones can provide sensitivities far greater than required for underwater use.

[redacted] He noted that for electrical machinery the system for collection of current dominates the geometry and size of new equipments. He cited

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developments of monolithic brush collectors for high power density electrical machinery, which will allow conventionally cooled machines to match superconducting machines in size and weight. He cited materials impact upon design simplification, or changes not easily seen, such as the increase in wear-life of splines to the point where they never need to be replaced in ship or submarine.

Dr. Kear gave an overview of developments, old and new, in laser materials processing technology. Laser welding already has many applications. The welding of ring frames to hull sections alone shows the possibility of reduction of over 60,000 man-hours and thus $1 million per submarine.

Laserglazing (surface melting followed by rapid solidification) is a relatively new technology with many possibilities. Bulk structures such as discs and drum rotors can be built up incrementally by laserglazing one thin layer on another. This gains a completely homogeneous, flaw-free structural part, is natural for computer control and near-net shape bodies, and can be combined with thermo-mechanical treatment to give material microstructures otherwise unattainable.

In-situ surface treatment to attain high temperature-corrosion resistance as well as shock hardening to improve fatigue properties are other examples. Dr. Bement added that laser treatment of aluminum can gain 30 to 40 percent in strength and 100°C in temperature use--so it is almost a new metal. Ultimately, Dr. Kear believes pulse annealing, ion-implantation, and laserglazing will develop into an integrated new technology for the surface treatment of materials with a wide range of structural and electronic applications.

Discussion brought out the possibilities for field use of laser welding (already used for pipelines) and laserglazing surface treatment. These were seen to be of great potential for field maintenance. Dr. Bement added further to field possibilities. He described the possibilities for in-field "cloning" from polymers or steel of replacement parts for existing or captured equipments. Three dimensional photography with autodigitalization would control casting of parts for automatic weapons, aircraft/missile or orthopedic needs. He noted this application might be put to intelligence purposes since similar photos of enemy equipment could be put onto digital tape for later reproduction.

Dr. Anderson stated geophysics is central to a few specialized military problems, such as missile guidance (gravity field) and weapons testing monitoring (seismology), but is also involved in such general problems as weather forecasting and control and submarine navigation, detection, and evasion. He emphasized the advances expected in geodetic instrumentation and technology including the multiple satellite sources. The results will show in missile accuracies, precision updating of ship and aircraft inertial systems, and so on. He believes DOD geodetic self-reliance can be expected to increase and argued for more interaction with others to pass on the gains in knowledge.

Separately, he identified a number of related developments of importance to national security but perhaps only indirectly to military capabilities. The direct detection of hydrocarbon resources by shear wave techniques should be industrial practice during the 1980s; and thereby the possibilities for the cheap discovery and early exploitation of these resources. The routine prediction of major earthquakes will make possible either disaster preparation or, the opportunity for covertly testing nuclear weapons. Routine six- to 10-day weather forecasts will be as good as today's two- to three-day forecasts; and along with a more basic understanding of weather modification, may come the technology to increase precipitation. Lastly, he noted materials are now being fabricated at one to 10 megabar pressures, which opens the possibilities that these new materials will possess unique physical and electrical properties.

Dr. Wunsch cited two major areas where ocean science relates to national security: the knowledge of the fluid ocean on the acoustic and operational environment of the Navy, and knowledge of the relationship between the ocean and possible climatic changes. He emphasized the extent to which we are now ignorant of the ocean as compared to the atmosphere. Now, a very few observations and a rudimentary knowledge of physics form our knowledge, but in 20 years he expects a reporting network much like now exists for the atmosphere and a real understanding of ocean weather and climates. Acoustic sounding, satellites, and advances in computer techniques will make this possible.

He predicted that in 20 years we will have the capability for large-scale global monitoring of ocean weather systems with a forecast ability equivalent to what is available today for the atmosphere. This will have an enormous

impact on vessel routing, ASW (acoustic propagation and tracking) capabilities, tactics, and upon weather-climate forecasts. We will also have greater understanding of the role of ocean circulation in climate change. It is now believed the ocean carries as much heat poleward from the equator as does the atmosphere, but where and by what mechanism? Clearly with this magnitude, the ocean plays a major role in regional and global climate flux. The understanding may enable the forecast of major changes far enough in advance to alleviate catastrophic outcomes.

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advances in fiber optics and laser technologies for ignition systems. However, the potential for more than evolutionary change he identified with the electromagnetic gun. The concept would employ a projectile with a magnetic coil propelled out a tube by a linear electric motor. A prototype exists. The "Mass Driver" was constructed by an instructor and students at MIT to demonstrate outer space transport, but has about one-tenth the energy of a small mortar. The technology exists to undertake a moderately scaled gun version.

He cited the potential advantages of an electromagnetic gun. Some of these are precise control of projectile energy; elimination of gun tube wear, flash, smoke, etc.; rapid fire; ease of supply; and no propellant charge, no propellant surveillance, etc. The propulsion could be provided entirely electromagnetically or in a hybrid system where some electromagnetic energy is used as an adjustment--with different degrees of these advantages gained.

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STRATEGY AND TECHNOLOGY

The form future conflict may take is naturally an important consideration in determining which technologies are militarily significant. Military requirements and planning are frequently labeled as "refighting the last war." Thus conflict considerations were introduced on the basis of their plausibility without regard to compliance with mainstream forces planning.

Even then, Dr. Stevens noted that too much of past analysis has been constrained by overattention to plausibility. In response, he suggested that the unknowns of the future, such as those sampled in these discussions, argue for broad capabilities in US forces.

Ideally, these sessions would have characterized the environment to be faced. Instead the materials discussed and recorded represent pieces for consideration, not a full treatment. However incomplete, they do reflect significant views of prime considerations for future needs. A few examples were offered of how technical priorities might be altered, but much fuller treatment is obviously required.

Overview

Mr. Kahn in his overview of strategy and technology stated that the level of strategic debate in the US today is at least an order of magnitude lower than 15 years ago. He particularly noted US focus on strategic forces as if they were only to respond to an out-of-the-blue attack upon the US. Similarly, we think about NATO forces as if the Warsaw Pact were expected at any day to grab Europe. He argued that most people consider these the least likely, and they are correct; but our planning and force choices have yet to catch up.

He expressed no doubt that the USSR would like to control the world, but stressed that while the Soviets may believe it necessary to push history in their direction they are unlikely to rush it. He saw the Soviets' emphasis on strength as very basic. First, if a crisis does occur and they are strong, the other side will back down. Second, if

they overextend and get into trouble, their large superiority will rescue them. And third, Finlandization of Europe is possible through recognition of Soviet superiority. These indeed are cause for us to be concerned over their strength; but we need fresh views in our response, especially as we view the future.

He argued that war, if it is to come about will not be calculated, nor out of the blue, but rather from a period of tension, with accidents leading to escalation. He cited two critical considerations for examination of strategic forces; namely, what is our goal at the end of the war and what is the importance of evacuation.

He thought for conventional war the most important consideration was the recognition that a buildup of tensions, perhaps even "phony war," would precede major hostilities; and thus a period for mobilization would exist. His second point about conventional war was the need to look at our best systems differently--one side forgets something, the winner does not; all fortresses are invulnerable before the attack, only some are found to be so after the attack.

Dr. Rechtin summarized the sober view toward NATO warfare taken away by most. He said many past questions and dilemmas about Soviet directions had been clarified. The Soviets appear more predictable than we had thought.

The Soviets are thinking about World War II technologically extended; that is, continuous-nuclear-biological-chemical warfare. This is what they are set up to do. The message has yet to be passed to US technologists and systems designers, but it seems clear that we must responsibly design to meet this threat.

Non-Mutual Assured Destruction

Dr. Durbin said the contingency of massive Soviet attack out of the blue against the US, followed by immediate and massive US retaliation has been the cornerstone of US planning for almost three decades. Deterrence is attributed to this posture of mutual assured destruction (MAD) or balance of terror, as both populations are thereby held hostage. Each offense must be overwhelming and the defense emasculated. This situation may in fact be the correct one for force sizing and decisions on alert posture; but it is not the only situation possible and in fact is not even the most plausible.

Limited selective or controlled use of central strategic nuclear weapons has been publicly discussed in the United States since 1974. Yet it is unlikely that either the US or the USSR can obtain any meaningful unilateral advantage through limited use of nuclear weapons against homelands. Use of these weapons in a local theater, especially on the Soviet periphery, is likely to be met in-kind in the theater. Either situation is likely to result in the rapid search for de-escalation and termination, with concurrent concern for alert and monitoring.

The threat to use tactical nuclear forces to back up inadequate conventional forces in Europe has been the basis of the NATO posture for the same three decades. The relationship of these forces to those of the strategic forces has never been explicit even before the current concerns over the SS-20, cruise missiles and Backfire Bomber. Furthermore, how does the survivability of these theater forces, their mix, and their use after a massive exchange relate to the MAD concept?

Lastly, what is the outcome of a massive nuclear war likely to be? An examination of the capability for a Soviet first-strike counterforce shows it to be formidable, although not likely decisive. Examination of survivability and recovery of population, industry, and the economy presents numerous unknowns, but certainly indicates survival of and recovery from massive nuclear war to be realistic. The civil defense, hardening, and defensive measures for Soviet forces indicates they hold the view that nuclear war is survivable. Then, what is the possibility of continued hostilities and the role of other countries? What are the mix of weapons and forces left, the nature and capabilities of the surviving leadership, the degree of control over remaining forces, the available communications, intelligence and reconnaissance, and what is required to restore deterrence after nuclear weapons have once been used massively?

The limited use of nuclear weapons, the theater-war relationships and the Soviet recovery, civil defense, and counterforce capability argue that the MAD strategy is insufficient for deterrence. A broader perspective, which ensures the existence of a nuclear war-fighting capability vis-a-vis the USSR, may evolve as the determinant for strategic forces. This would provide a deterrence posture more consistent with views held by the USSR--and thus more likely to deter. The measures for strategic forces utility would shift. Correlation guidance for cruise missiles attacking a badly damaged nation would be examined. Even greater emphasis

would be given to survivability. New emphasis would be given to holding capability, reconstitutability, reload, re-targeting, and reconnaissance. The old concept of an emasculated defense might be replaced with the possibilities for effective defense from space against ballistic missile attack.

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World of Nuclear Proliferation

Mr. Rowen drew upon his prior writings "Life in a Nuclear Crowd" to describe the likely spread of nuclear weapons. He noted that despite a good deal of rhetoric justifying national nuclear weapons programs, few of the countries with the capacity to make them have done so. Two developments now promise fundamental changes: one is growth in civilian nuclear programs and therefore an increased capacity to acquire nuclear weapons cheaply and rapidly; the other is a weakening of confidence in American guarantees of protection of allies.

By 1985 about 40 countries will have enough fissile material to make three bombs or more; almost as many are likely to have enough fissile material for 30 to 60 weapons or more. The Indian nuclear explosion of 1974 may have been the crucial "triggering" event between a linear growth in nuclear weapons acquisition, and an exponential future. The prospect that many countries will acquire weapons must be taken seriously, as must the short leadtime within which these weapons can be acquired.

Most analysis of nuclear stability is based upon a model of the US-USSR relationship, with exclusive concentration by the two great powers on deterring attack on each other's homelands. The possession of nuclear weapons by third countries is likely to bring about changes such as restraint by a large power in challenging what might be construed by the smaller as its vital interests. Between small powers, the relationships are likely to change with a race to acquire weapons first, and with support provided by the large countries in technology, in the reduction of forces vulnerability, in replacement of nuclear forces destroyed or in direct use of nuclear weapons against an

ally's adversary. The nuclear forces of small nations will be small, probably without reliable systems to warn of enemy attack, and perhaps weak in safeguards against unauthorized actions by those in the chain of command, and prone to accidents and mistakes. The large powers will possess many more resources for information gathering, offensive capabilities, command and control, civil defenses, antimissile and air defenses, etc. as well as the capacity to rapidly transfer technologies or information which could rapidly make opposing forces vulnerable or reduce the dangers of unauthorized use.

The countries most likely to acquire weapons are the nonaligned and marginally aligned countries, and those that feel threatened and fear abandonment. India, Pakistan, Iran, the Republic of Korea, Taiwan, Israel, South Africa, Argentina, and Brazil are some of nations with such rationales. Proliferation will increase the need for alliances among those countries threatened by rivals acquiring nuclear weapons. However, it is not clear that the great powers will be willing to make guarantees to countries with nuclear weapons on the grounds these weapons are no longer needed, nor to nations in a region with nuclear powers because it may be too dangerous. The potential for nuclear spread will have only been partially realized by 1985; many more potential entrants will remain during the following decade. Acquisition will likely depend upon the availability of materials and technologies, what happens to the countries that have acquired weapons, and the degree of security provided by alliance relationships.

US concerns, other than the instability that may follow from proliferation, are likely to be the intentional or unintentional use of nuclear weapons against US forces abroad, the use among third nations to which we may or may not be allied, the threat to US territory by another country or terrorists, and the accidental or unexplained incident.

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Mr. Rowen made clear that the main task is not just to forecast, but to try and influence the process toward nonproliferation. The discussion touched upon policies, practices, alliance relationships, and providing of nonnuclear

capabilities and cooperative international efforts to reduce terrorist possibilities. The prospects for control over materials and technical knowledge were considered by most to be too late and too little.

NATO War

Mr. Emanski drew attention to the characteristics expected of future land combat in Europe. He emphasized continuous combat because the Soviets have established it as their doctrine and equipped themselves to carry it off. Savkin's "Operational Art and Tactics" establishes the duration of the continuous offensive to be between 30 days and 8 weeks. The Soviet concept is to echelon forces so that the intensity of the offensive can be maintained at the points of combat contact along the main thrusts.

However, he noted that continuous combat would have evolved without a Soviet emphasis because it is a logical projection in the trends of warfare. Trends noted were:

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The dimensions of continuous combat are far-reaching, much more is necessary than simply emphasis on night operations. Fundamental changes in doctrine, organization, training and equipment are involved. The tempo of operations will increase as the present discontinuous or intermittent operating capability is replaced by sustained combat.

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Mr. Emanski observed that there are not three separate Soviet doctrines for chemical, nuclear, or conventional war. There is one. Soviet operational hardware includes protective garments, chemical warfare antidotes, automatic CBR alarms, sealed vehicles, a complete family of decontamination/washdown equipment, protected medical vans, a family of chemical smokes and aerosol generators, and so on. Nuclear and other weapons of mass destruction, chemical and biological, do not reduce the importance of continuous combat but rather underscore the reason this is likely to be the character of the next war. The point was brought out in discussions that while the US developed the neutron bomb, ostensively as a defensive weapon, it would be in fact a natural weapon for the Soviet style offensive since rapid movement into the target area is one of its desirable characteristics.

Two other characteristics for future warfare in Europe were identified by Mr. Emanski. First, it will be a coalition war and interoperability of doctrine, equipment, procedures, communications, and command and control is fundamental. A team wherein one-fifth of its members are playing one game while the other four-fifths play a separate game or games cannot expect to win. Second, military operations in built-up areas are unavoidable.

Mr. Greene added to the second point noting the continuing urbanization of Western Europe. This degree of urbanization will make obsolete NATO's long-standing strategy for forward defense using tactics designed for operations in open country. This is particularly evident in the North German Plain, which has historically provided the best east-to-west route for invading armies. Three urban complexes alone will cover 40 percent of the total NORTHAG-Second ATAF region by the

year 2000. These large areas could be an enormous liability to the defense of NATO, or they offer outstanding possibilities for improved defense if appropriate strategy, tactics, and equipments are developed and deployed.

Much discussion focused on these concepts for warfare in Europe. The perspective of Soviet developments leading toward a continuous warfare capability had clearly gone unrecognized by many. Also unrecognized was the extent of Soviet preparations for theater nuclear, biological, and chemical warfare made pointedly clear in the colloquium by Emanski, Greene and Augerson.

The result was a sobering appreciation of the situation likely to be faced in a European war. Mr. Emanski noted that the most significant benefit from recognition that continuous combat will be the nature of future battle would be the unifying purpose this could bring to all combat and material developments.

Information War

Dr. Rona stressed the conceptual aspects of countermeasures to make a number of points about the future of information disruption, manipulation, and misimprinting--information war. He noted the spectacular advances that have taken place in military technology--namely, propulsion, guidance, and warheads--so that whenever a weapon can be aimed at its assigned target it is highly likely the target will be destroyed. Protection in the past has depended on target hardening, target mobility, or timely counterattacks. Protection in the future will depend more and more on misinformation or information denial.

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The future, as he saw it, will tend to reinforce new and sophisticated ways to apply countermeasures in their broadest sense; especially as technology opens possibilities for and vulnerabilities to transformation of about any physical phenomenon into electrical signals with the attendant capability for transmission, processing, and display. He added some predictions. The use of target-connected observables for high-accuracy terminal guidance of missiles will be avoided whenever possible. They are likely to be under the control of the enemy and therefore amenable to relatively inexpensive countermeasures. The trend will be away from high-value, concentrated, mobile platforms, to a number of relatively small, possibly unmanned platforms, synchronized by secure wideband data links. (The high asset concentration represented by the Trident weapon system must be seen as an anomaly in this respect.) The trend toward a large number of cooperative elements will permit design of small but significant individual differences thereby providing multiple-complexions for the enemy to face. Space-borne surveillance will reduce or eliminate depending upon emissions direction-finding and thereby shift the emphasis from silence (e.g. by ocean vehicle) to one of open broadcast where the emphasis is upon achievement of confusion and disinformation. The trend will be toward one-time-use systems such as an unmanned precursor penetrator to deploy local beacons for temporary target attack. C-Cubed systems will be adaptable to rapidly changing combat environments, including the confusion messages deliberately provided by the enemy days, weeks, months, or even years before the actual start of overt hostilities. Finally, equipment for training people to handle various aspects of information war will be important, in particular for the training of military people with different cultural backgrounds.

During discussion Dr. Rona suggested two changes that would be an important response to these futures. First is the imperative need to address the information war-related moves throughout the whole evaluation and operational life of newly proposed or upgraded weapon systems. By contrast, attention to countermeasures is now an afterthought frequently lost in budget cuts. Second, a C-Cubed/intelligence simulation laboratory is needed to explicitly focus on the stressed behavior of complex combinations of high-performance links and human interface under conditions of an unintentionally or intentionally distorted reference base. This laboratory could aid training as well.

Small Unit Operations

Nonintervention as a defined or undefined national policy is perhaps a rationale for inattention to small combat units. Yet hazardous politico-military operations such as "surgical strikes" in support of antinuclear proliferation or assurance of energy supplies, the rescue of hostages from terrorist groups, and selective antiguerrilla operations are anticipated by many as likely low-level conflict needs for small units over the next two decades. Wartime raids against critical high-value behind-the-lines targets form yet another role for specialized small unit operations. General Henderson acknowledged these roles, but presented a broader view of small tactical units applicable at all conflict intensity levels and in all geographic environments.

He argued that the expanded combat capabilities which technology could give the small tactical unit would change and dictate the nature of ground combat in scenarios foreseen and unforeseen. He noted the area controlled by a large force (approximately 100,000 men) increased by five between the Civil War and World War I, by 12 between World War I and World War II, and by 10 since World War II. He said another gain of this magnitude is possible by the end of this century, that is, 30 to 50 man units could control a four-square-mile area against the Warsaw Pact or nearly the equivalent of today's infantry battalion. But this benefit cannot be realized if we merely applique modern technology in a random fashion to present day small combat units and their operating concepts--the small unit must be developed as a truly integrated combat system in a manner analagous to that for a new tactical aircraft.

The small unit can have a terminal in global and local positioning systems to locate and to direct supporting fire. It can have the capability to transmit voice, digital and video to support units. Automatic attention and output interpretation from line-of-sight and non-line-of-sight sensors can eliminate constant operator attention while providing detection and identification of physical objects and emitters. Deception and decoy devices can be available for those most likely to be detected and attacked by an advanced technology enemy force. Organic multipurpose precision weapons utilizing nuclear, electromagnetic pulse (EMP), nonlethal CW and conventional munitions can be carried for use against ground and air vehicles, structures, area targets,

and electromagnetic emitters. Development of the combat unit as a system is the key to realization of these capabilities for large force conventional or nuclear conflict. It is also the key to the versatility and effectiveness of modified units for independent operations. The infyonics concept, so labeled by General Henderson, prompted exciting discussion. Many readily appreciated the significance of small units if the promised gains of new technologies were to be realized in large force operations. They also appreciated the ready spillover of this focus for development of small, independent teams. However, there was much doubt that even recognition of these possibilities could overcome the old habits of emphasizing the hardware.

Food/Water Crisis

Dr. Doty cited the production and distribution of food as a potential security concern. Vulnerability exists because of the increased dependence on a relatively few species which for the most part do not have high resilience to unusual infections or unusual variations in growing conditions. The development and nurturing of new genetic species and the storage of seed stores are logical defenses. He foresees these, and vigilance against destructive acts, as elements of national security in the 1990s.

Dr. Anderson drew attention to water as an essential natural resource. Historically, the demands on water have increased and will likely continue to do so. Economic growth has not only stressed water supplies but, coupled with land-use practices, water quality as well. We lack understanding and modeling capabilities of water quality and its attendant geochemical, biological, and hydrologic controls, particularly regarding persistent toxic substances. The issues of food and energy will invariably stress the resources further. Whether climatic shifts will occur, ameliorating or aggravating the imbalances of supply and demand is uncertain.

National security has not been defined as an objective of water planning. Had chance not conspired to end the 1930s drought before the nation entered World War II, the consequences would have been harsher. He concluded by noting that the resource systems evolved during the quiescent periods may well lack the resilience to respond to the demands that might be imposed upon them during periods of national stress.

Energy-Related Scenarios

The technologies of energy were not addressed in the colloquium, except for the [redacted], electro-magnetic gun, and some vehicle propulsion ideas. Energy as a source of conflict was to have been included in the colloquium, however, the speaker who was to have discussed this topic was unable to attend. A few of the points that would have been addressed are included here in order to add to the forecast considerations.

Increased world dependence upon oil through the rest of this century is accepted even among those with optimistic predictions for coal, nuclear, and solar power applications. This creates a number of potential security problems. The United States itself depends directly on sources in the Middle East. Military contingencies must protect these sources and their supply lines from acts by the Soviets, by hostile Middle Eastern nations, and by terrorist groups.

Our major allies, Western Europe and Japan, are more dependent on these sources and lines than is the US. Thus protection of these sources and supply lines is essential to their economies in peacetime and critical to their existence and the conduct of defensive military operations in wartime. Concern over continuous theater war seldom addresses this vital supply question. However, far short of war, the more critical dependence of these nations upon outside sources is likely to bring about differences with the US which may alter alliances during these next two decades.

The Soviet Union now exports oil to Eastern and Western Europe. Many estimate that it will be unable to increase its production sufficiently beyond the early 1980s to maintain this favorable position. A further pinch in their economy may result, as noted in the remarks by Mr. Earle. Reduced supplies to East Europe may in turn cause these nations to depend more upon Middle East sources and to seek more Western hard currency to buy Middle East oil. If the Soviet Union's shortfall were severe enough, it could become an importer of oil and thus an active competitor for Middle East oil sources.

Japan, the People's Republic of China, Taiwan and Korea are potential competitors or collaborators in the development of oil in the East China Sea. The less developed nations (LDC) in their attempts to industrialize have no choice but to depend upon oil and thus to compete with the industrialized nations for the available supplies. Frustration and instability are certainly likely.

Overall, two points were to have been made by introduction of this topic into the colloquium: first, that energy supplies, particularly oil, are unquestionably a source of tension and possible conflict during the next two decades; second, that access to these supplies may even more importantly become the cause for change in current alliances and the creation of formal or informal alliances between nations now presumed to be neutral or joined in common interests with the US or the USSR.

RESOURCES & UNCERTAINTIES - USSR

The Soviets' military competition was identified as serious. Examples of good Soviet design, and of their impressive match of doctrine and equipment were given throughout the colloquium. Their nuclear-biological-chemical capabilities drew special attention.

Dr. Stevens pointed out the inexorable commitment of the Soviets to expenditures in defense and to maintenance of a technological capability different than our program-by-program approach. He noted on the other hand the inertia of their system and the difficulties which they admit to themselves are likely to hinder their application of high technology. The forecast these may present was debated but certainly not resolved during the colloquium.

Past analysis has innately assumed the Soviets to be a mirror image of ourselves. Dr. Stevens noted our knowledge of the Soviets, as illustrated during these discussions, now is far greater than during the past decades. Consequently, we can in fact be more selective in what we choose to pursue to gain advantage for our forces.

Soviet Resources

Mr. Earle presented an overview of the generally accepted estimate of decline in the Soviet economy; a decline in annual growth from 4.5 percent currently to a 3 percent during the later part of this century. This estimate is based upon limitations in the work force, insufficient energy production, along with the Soviets' normal problems with agriculture. European perceptions are less negative and tend to project growth of the economy at current rates. The Europeans do not foresee the energy problems for the USSR to be as severe as seen by US estimators.

The Soviet leadership does see problems ahead and does appear to recognize that this means allocation difficulties. However, it has not developed an economic strategy yet. The next five-year plan, expected in 1980, might give insights to the choices. But he thought it unlikely and suggested the Soviets would probably wait out the period and make changes in the subsequent plan.

Foreign technology is a source of improvement for the Soviet economy. Thus far the Soviets have concentrated on achieving bulk additions to their capacity. Difficulties in absorption continue, but clear gains have been made.

Beyond the question of how much gain, the basic question is whether the USSR will make a long-term commitment to be part of the world economy, or whether it will once again withdraw into isolation. The exports it has developed have paradoxically been products of high internal demand (autos for example). However, this may be an example of conservative planning in that should the products fail in the export market they can readily convert to fill domestic needs.

Projections of economic growth lead to projections of defense expenditures. US estimators have previously disagreed with the low numbers held by the CIA. The higher CIA numbers now do not resolve the questions, as the shape of the expenditures curve still does not reflect force deployments. It is one thing to say what a number is not, it is quite another thing to say what it is.

A decline in the rate of growth of Soviet defense expenditures is projected. But the actual expenditures are significant, and Mr. Earle estimated long-term growth of defense expenditures at 4 to 6 percent annually; that is growth faster than their overall economy. The military sector is also expected to become more productive. He cautioned that we should not look at the Soviet economy in our terms. A stable economy, even if sluggish, is desirable for the USSR. Opportunity costs are not viewed with the disdain they are in the West, and thus the "burden" of military expenditures is less troublesome. In comparative terms, as the Soviets view the current turmoil and problems of the Western economies they can live with their own problems more comfortably.

Soviet R&D Patterns

The basic point made by Earle and Alexander was that in comparing the US and USSR, we must think more in terms of Soviet process. Dr. Alexander noted that evaluations of US and Soviet military R&D often begin and unfortunately end with inputs (budgets, engineers, educational levels, and so on). However, given a gross comparability of inputs, it is in the process and choice that sharp differences emerge between US and Soviet practice.

Dr. Rechtin gave examples from his experience with the DOD where repeated assumptions were made that the Soviets would use their comparable, or enormous, R&D investment to close military technological gaps. Instead they apparently have not seen our leads as that important for they have used their resources quite differently than we.

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Dr. Alexander identified recognized features for the bulk of Soviet military acquisitions as simplicity in equipment; common use of subsystems, components and parts; incremental growth; and limited performance and mission capabilities. This pattern has been pervasive in the past and is likely to be so into the future. We have now acquired a fundamental understanding and data that can enable us to make sounder judgments of future Soviet capabilities--and thus to be able to be more selective in our response.

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RESOURCES & UNCERTAINTIES - US

Concern was expressed throughout the colloquium that the threat and problems not be overstated--but be credible. The United States possesses fundamental economic, technological, industrial, and military strengths. More generally, the industrially more advanced Western nations (NATO) have a population of 560 million in contrast to the Warsaw Pact population of 365 million and have a combined GNP over twice as large as that of the Warsaw Pact. Clearly, adequate resources are available.

Clear as well is that we in the United States have much technology across all fields. The state of the art is high. The presentations and discussions covered an impressive array of our technological capabilities. Priorities likely to maximize the leverage for the United States were suggested for DOD technical resources.

Dr. Davis said the colloquium showed the military systems to be beneficiaries of many technological options, and not the captive of shortfalls. The presentations in 26 areas of technology provided reasonable comfort that desired competition in technology will occur and is adequate for intelligent selection of a few system efforts with a high probability of operational success.

She emphasized that continued competition within the US in technology is inexpensive; and should be proportional to potential payoff, scientific uncertainties, and the quantity of systems/components planned for procurement. Demanding a winner before beginning R&D encourages a stifling conservatism in contrast to a stimulating innovativeness.

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Technology As An Equalizer

Dr. Davis cited some group opinions that had evolved. She noted that in the view of many we have fewer problems generating new technology than in translating that technology into fielded equipment. Dr. Lukasik noted that the time between technology "generations" in a number of important areas cited as less than the DOD procurement cycle. The DOD acquisition process was seen to unwittingly degrade our technological advantage and thereby equalize the US and Soviet military prowess. We wish to meet the threat by using high technology; and thus we must be concerned by impediments.

Dr. Berenson echoed the keynote charge--the key question is what technological initiatives should the US take in the near term to make the maximum increase in relative total deployed military capabilities in the next 10 to 20 years. [redacted] STAT

We need to develop ways to decrease the time from the availability of technology to full operational capability of the system. Dr. Berenson emphasized that production, training and maintenance technologies are important in addition to the weapons system level of technology.

None doubted the fundamental technological strength of the United States or in a larger context that of the West as a whole. The USSR's "worship" of science, coupled with their respect for Western technology adds to our basic strength. Recognition of the seriousness and character of past and current failings, and corrective actions, were seen to be critical to the national security and to realization of the benefits from our technological strength.

The colloquium discussions offered insights both for significance of technologies and therefore selection. Insights for more rapid assimilation of technology are recorded in this section. The point made vividly by several operational personnel was that our technological superiority is not obvious to the man in the field. We cannot gain the leverage we desire from our technology by selection alone, we must focus on its assimilation into military operations.

Numbers Are Important

This message was one that most participants put forward. [redacted] The fear was that technological superiority or quality versus quantity has been for too long a cliche preventing necessary investment in mass. Extracts from a 1976 speech by Senator Sam Nunn of Georgia expressed this point for most: STAT

--At some point numbers do count.

--At some point technology fails to offset mass.

--At some point Kipling's "thin red line of heroes" gives way.

The approximately 3 to 1 ratio of procurement to research and development was cited as clearly disbalanced--with note that industry figures are more like 10 to 1. Some concluded the technology investment was about right and the procurement should therefore be increased. Others said the need for numbers was serious enough to warrant sacrifice from the R&D budget so equipments could be procured for the field. This emphasis does not mean to buy ships to counter ships, tanks to counter tanks, and aircraft to counter aircraft--although that is indeed part of the answer. Clearly it also means a skeptical examination of the purported claims for one-on-one performance, where the alternative is more of a cheaper version, and it also means emphasis upon surveillance and command-communications where these can affect appropriate massing or avoidance of disadvantageous combat.

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US hardware and software R&D has outrun what may be termed operational R&D--or learning what it is good for. Furthermore, we know that equipment by itself is not the answer, but rather the combination of the right tactics and the equipment as used by men. The development of tactics, or assimilation of the technology, depends upon the existence and use of numbers.

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Design For Mobilization

Mr. Kahn drew upon history to make a major point. The debates of June 1950 were whether the United States could afford a $14 to $18 billion defense budget. The Korean War began and Congress authorized $60 billion. The consequence was that we were able to afford such systems as the B-47, B-52 and Minuteman, none of which singularly would have been affordable under the expected service allocation of $5 billion annually. Our military superiority sprang from this jump.

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This priority would mean investment in long lead items. More importantly it would mean experimentation and design with a view to rapid expansion of our capabilities. That very well could mean deemphasizing from "ultimate" designs in favor of simpler designs, and deemphasizing from one-for-one replacement of ships, tanks and aircraft in favor of the command and support systems. Other answers exist--Mr. Kahn's point was that the capability for force expansion not only is historically sound, but would generate desired design directions.

Operations R&D

Dr. Lukasik described one of the more important suggestions put forward for change in the acquisition processes as "operations R&D." The concept is to achieve evolution through operational exercises and use; and while obviously not applicable across-the-board, it could be instrumental in the development of many new uses, new doctrine, and the actual assimilation of new technology.

This change was suggested to address what many saw as a major failing of the acquisition system. That is, the presumption that each system is forever, and therefore its characteristics must embody all future requirements--and axiomatically all the latest technologies at its IOC.

The technologies of the future lend themselves to incremental update of systems. The conflicts of the future are likely to require adaptation. A point, already noted, was that while the research and development community can hypothesize the use, it really can not know. These, most participants argued, are cause for explicit emphasis within acquisition for field evaluation and experimentation with many new equipments in order to learn of their use and to feed back design changes. Innovation and rapid assimilation of technology were seen as the gains; but time and money needs to be explicitly provided within the acquisition cycle in order to achieve these gains.

[redacted] United States should possess great advantage for leverage from the processing explosion in contrast with the USSR. But second, that this potential is unlikely to be realized unless we can focus on experimentation and evolution along the lines brought out throughout the discussions: infyonics, distributed systems, life sciences, naval surveillance, microprocessors, and so on.

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Adm. Martell suggested further gains. He agreed with the view of many that the most likely events of the next decades were those of crisis, incidents, and challenges. He related future responses to new challenges, in possibly new geographical areas, to Mr. Kahn's point about emphasis upon experimentation and designs for rapid expansion of capabilities. He gave an admittedly parochial example: the need not to buy for the fleet, but to experiment with droppable sonar buoys which could be read out by satellites.

His fundamental point was that normal budget activities, which focus on platforms, on mission definitions, and on life-cycle costs, leave no room for such small quantity experimentation and learning. These procedures force a "commitment" to buy and deploy--after a cost-effectiveness comparison with other future buys--even before the experimentation takes place. Cheap learning, and possibilities for expansion to meet new contingencies, are thereby forgone. Rather, money, labs, test organizations, firms and operational units must be pulled together and given the opportunity, or even the explicit assignment, to undertake the test for operational possibilities and problems before commitment.

Innovation In US

The incentives and disincentives for innovation in the US were the topic of an evening session at which Mr. Oliver Boileau, President of Boeing Aerospace Company, and Dr. Robert Noyce, Charman of INTEL, spoke. However, discussion was not limited to this session, as the contrast between the technically possible and the deployed prevailed throughout the colloquium. Both a strong sense of frustration and some suggestions for new directions were recorded. The topic is particularly apt, since a long list of the technical possibilities cannot comprise a forecast; but rather these possibilities must be overlayed with trends that will bring forward or constrain them.

Mr. Boileau cited the fundamental advantages this country has in its industrial and technological base. He then addressed the inability to move technology into inventory from a defense contractor's viewpoint. He identified the government as the greatest inhibitor today, both the regulations and the management processes. The latter is best illustrated by the question of who is the customer: the Service program office and boards, the DSARC, the Defense Secretary, OMB, the President or the Congress. These comprise a hydraheaded buyer, any mouth of which can say no before a system can be put into production long enough to make money for the firm.

He addressed a common misunderstanding. Government funding of developmental work does not cover all costs. If you are innovating, industry must dip into its own resources. BAC invested $50 million of its funds in the recently canceled Advanced Medium STOL Transport (AMST); but increasing losses from cancellations make it tougher to justify future investments. Boileau's point was not to create a taboo against program cancellation; but rather that this intolerable lack of common purpose and apparent national will to maintain a strong defense undermines innovation.

Innovation funding, or the problems associated with obtaining these, recurred throughout discussions. Mr. Boileau contrasted the commercial marketplace incentives with those of defense. The former have been substantial enough in the past for Boeing to periodically risk its entire net worth to bring out the next-generation product. He noted that in current dollars, Boeing put 1.7 billion into the 747. The point is real even though the contrast of defense and commercial incentives may not be as drastic. BAC does invest heavily in IR&D for defense; and a recent Fortune article noted the potential sizable Northrop commitment but not its entire worth to the F-18. Funds for commercial innovation are not readily available either, as Dr. Noyce made clear, citing the trend over the past five years. This problem stemmed from tax disincentives, from available money going into short-term returns, and from investment houses unwilling to put money behind technology without assurance of Xerox-like performance.

Others maintained that cautious attitude within government laboratories inhibiting both innovation activities in the laboratories or the funding of innovation outside. Freedom to expend at least limited sums and manpower without defendable mission results or assurances of success has disappeared. This was seen in part to be the lack of

"great directors," but likely more attributable to the hyperactivity of budget and "exposure-minded" reviewers and media. Lastly, note was made of the difficulties for universities to obtain research funding. The expenditure of time and money to obtain a research dollar have become excessive to the point where they inhibit active research.

Dr. Noyce made a strong pitch for increased government funding of university research--but with greatly reduced red tape. He argued that this is where the future innovative industries, such as that of semiconductors, must begin. By contrast, research within private firms is inadequate, their research is not shared, nor is it directed at other than short-term interests, e.g. defensive in nature. Furthermore, the technologists trained through research in the universities are the source of our innovative manpower.

Different viewpoints were given on the problem of government regulations and procurement practices. Mr. Dale Church (Deputy Under Secretary of Defense R&E for Acquisition Policy) described the effort under way to rewrite the procurement regulations, the ASPRs. Simplification and incentives for industrial motivation, including profits, are sought through these changes rather than relying on regulations. Several discussants expressed caution over the expectation that changed instructions, by themselves, would have much effect without extensive re-education for all throughout the government involved in the administration of procurement.

Dr. Rechtin pointed out that much government regulation has come about because some in industry lobbied for the regulation and cited a number of examples. He pointed out that if less constriction is to come about, an industrywide willingness to operate in a more competitive environment will be necessary.

Mr. Boileau's example of the AMST cancellation brought out another point. The Soviets announced their intention to produce their smaller version of the AMST about the time the US announced cancellation. It apparently uses the upper-surface blowing technique developed by Boeing, it has the same engine placement, landing gear, and so on. Thus the Soviets are gaining experience with our innovation, while our knowledge rests in file drawers.

Dr. Alexander separately noted one of the reasons for Soviet weapon effectiveness lies in the extensive field testing of new equipments within large-scale exercises as

part of the acquisition process--that is, the explicit determination of the military utility of the equipment and its features. Many expressed the belief that the US could accelerate the choice of and assimilation of new technology for military equipment if similar emphasis were given to operational unit evaluation and experimentation. US unwillingness to explicitly provide funds and scheduled time for such experimentation was seen as a major impediment to both useful innovation and effective assimilation of new technology.

The 10-year acquisition cycle was repeatedly cited as outrageous because it means much of the technology embodied is at least a decade old by the time it's deployed, because it means stretch-out costs are unavoidable, and because a malaise sets upon those in the technical and systems fields. Dr. Noyce noted that in the commercial market you do not tell the customer about your future line, or you will not be able to sell your current line. Many thought this version of "the best is the enemy of the good" explained much of the long acquisition cycle. Military requirements were seen to be less real than a statement of future technical promises. Designer-managers of military systems were seen to de-emphasize design simplicity and thus unable to reject attempts to incorporate all advanced elements at once. Suggestions included the clear demarkation of technology efforts from those of systems development, more competitive and shorter-term systems development, and explicit use of field experimentation with new technology where the military utility needs to be shown.

Mr. Boileau returned several times to the point that when a need is seen to be serious someone steps forward and quickly separates the vital from the unimportant, the critical from the unessential, priorities are set, and red tape is cut. He and others cited examples drawn from wartime, a national purpose--such as putting a man on the moon--or a "skunkworks" type operation. However, the point many made is that the problem is not how to exploit technology for one project, but how to exploit technology across the spectrum of military activities. Industrial approaches were suggested, but caution was advised as to which experience should be drawn upon. General Henderson suggested that AT&T, not the Soviets nor the aerospace nor the automakers, might be a good model for the DOD to examine as applicable to its across-the-board activities.

Mr. Kahn outlined his view that economic growth could slow down, or even stop, not because of resource scarcities, pollution problems, nor complex organizational difficulties but solely because of indifference or even hostility to economic growth and advanced technology--a cultural change. Understanding the direction of cultural changes requires a grasp not only of how people conduct their everyday lives, but also of the aspirations and visions of various influential groups. As these visions are shared by more and more people then personal, public, social, and economic policies are altered to conform to these new directions. He cited 12 "new" emphases and trends in the US that are becoming increasingly influential and threatening economic growth: avoiding the risk of doing something positive by innovation because it cannot be evaluated and the development of general antitechnology, antieconomic attitudes were two of the more obviously appropriate to the discussion.

Mr. Boileau noted, that the media, playing to these attitudes, are responsible, directly or indirectly, for much of the delay in getting technological innovation into the field. They spread inordinate caution among the decision-makers--what Arthur Kantrowitz calls a period of "timidity's triumphs." He saw the growing disbalance in US-USSR strength as sufficient cause for immediate attention. Waiting for a crisis to suddenly change these cautionary attitudes and then saying "go" to technology exploitation is not the answer. Suggestions included a major national effort to cut away government-created disincentives; an honest comparison between the Warsaw Pact and NATO forces and the inevitable consequences of the Soviet ICBMs; and an honest campaign to demonstrate the positive gains of American know-how and entrepreneurial ability to advance the economic good and stability of the world.

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